

XI. PROCESS ANALYSIS AND SYNTHESIS

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A. PATTERN RECOGNITION IN SILHOUETTES

1. Objective

The immediate purpose of this investigation is to develop a theory that will serve as the basis for the construction of an electronic device that can simulate an important human pattern-recognition function not yet achieved by machines. This is the ability to recognize visual patterns in black-and-white figures by automatically extracting group-defining properties from sample figures. It should be noted that the machine that must recognize the common pattern among the figures must learn to do so by itself. The machine cannot be programmed in advance to perform certain operations that lead to the identification of a pattern, since the pattern to be recognized is not known in advance either by the machine or by its builder.

The object of this research is to apply this philosophy to a small but important class of figures and to develop methods that allow the characterization of these figures and their recognition with completely automatic equipment. The class of figures to be selected is the class of silhouettes formed by a single, closed curve whose entire interior is black and entire exterior is white.

This class is selected for study because it is simple enough to place in evidence the proposed self-learning technique without getting involved in a high degree of sophistication, which, it is feared, would cloud the conceptual simplicity of the fundamental approach.

2. Representation of Silhouettes

A silhouette, as it has been defined, is completely specified by its boundary, that is, a simple closed curve. A function utilizing this redundancy of the figure is defined on the closed curve so as to map the set of all silhouettes into a domain in function space. The mapping is one-to-one and is independent of the location and orientation of the silhouette with respect to the reference coordinate system. In general, functions contained in this domain are expressible only as solutions of an integral equation that states the condition that the curve forming the silhouette's boundary should be a closed curve. Particular subsets of solutions, however, can be found as linear manifolds of this domain, and they are readily expressible by means of orthogonal functions that completely span the linear manifolds. This is illustrated by Fig. XI-1. The physical significance of the linear subspaces is explained in terms of groups formed by the corresponding figures, which exhibit rotational and other symmetries.

(XI. PROCESS ANALYSIS AND SYNTHESIS)

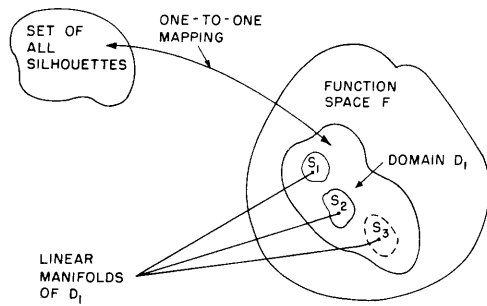


Fig. XI-1. Representation of silhouettes.

Even for figures that do not exhibit such symmetries, a general orthogonal expansion can be found in the form of a Fourier series with constraints on the coefficients. These constraints are responsible for the nonlinearity of the space D_1 in Fig. XI-1. The Fourier coefficients of the expansion of the particular point in D_1 into which a given silhouette is mapped afford a particularly simple way of storing the figure for further processing.

3. Variable Accuracy Storage

The method described in the preceding paragraph allows the storage of silhouettes in an economical form by extracting certain functionals that uniquely characterize the figure. From a storage point of view this is an important result. From a pattern-recognition point of view, however, this is not nearly enough. It is desired to extract functionals from the figure in such a way that certain tolerances established on the functionals will correspond to figures that are nearly alike or that belong to the same group. In other words, two figures that are close together as far as recognizability is concerned should result in functional representations that are also close together. This is by no means an easy task, nor is it one that is automatically satisfied by any functional. In effect, this requires the uniform convergence of the mapping which takes a figure from the space of silhouettes to function space when the metric that measures the similarity of two figures is not known.

4. Recognition

If the similarity of two figures is measured by a given class of properties, an automatic method evolved during this study can be used to weight the function description of the figures. The weighted function allows storage of the figure with the aid of functionals (Fourier coefficients of the weighted function) in such a way that the stored coefficients exhibit high sensitivity to distortions of the silhouette with respect to the given class of properties, and low sensitivity to other types of distortions.

This method maps figures that are similar in a given class of properties into the same neighborhood in D_2 , as illustrated in Fig. XI-2. No quantitative error analysis has

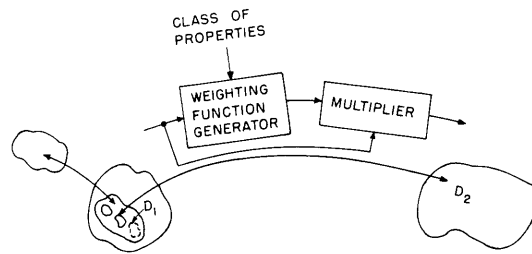


Fig. XI-2. Representation preserving similarity. (Fourier expansion of functions in D_2 are close if figures are close with respect to a given class of properties.)

been made as yet.

A technique has been developed which generates a four-dimensional surface in which the given class of properties is separated in a continuous manner into local properties of the silhouette and into properties more descriptive of the figure as a whole. One of the dimensions in this four-dimensional surface measures the degree of "localness" of the property. This four-dimensional space, for lack of a better name, is referred to as a property space.

Recognition of groups formed by figures that are well represented in terms of the given class of properties is accomplished by forming the intersection of the property-space representation of the figures comprising the group. In other words, the pattern is defined by the common properties of its samples. Note that an exact list of possible properties of the figure is not given to the machine. The machine is supplied only with the class to which the properties belong.

Our current work is centered on the problem of automatically extracting the class of suitable properties from the silhouettes themselves.

Details of this work will be described in a forthcoming doctoral thesis which will be presented to the Department of Electrical Engineering, M.I.T.

G. Sebestyen

B. A SELF-ORGANIZING SYSTEM

The goal of this project is to develop a method of extracting information from a specially prepared photographic frame, transmitting and receiving this information, recording the resulting organization, and eventually comparing output with input.

Work thus far has involved preliminary designs for a scanning device, an evaluation system, a selection device, and a device for organizing the selections. The major details of the design are complete, and circuitry for the electronic devices is under development.

The dynamics of a human body affords a subject that represents complexity of motion

(XI. PROCESS ANALYSIS AND SYNTHESIS)

coupled with rapidity of operating time. Our subject will be an isomerism of the human body; the dynamics will be a restrictive dance routine.

The photographic frames that we use are prepared by affixing groups of lights, referred to as arrows, strategically about the body and extremities of a professional dancer. The dance routine is restricted to the motion of seven specified parts of the body about prescribed joints and in a single plane. This activity is photographed with a motion-picture camera. The film is developed in such a manner that only the arrows appear. The information with regard to coordinates, orientation, and identification of the individual arrows is extracted by means of a multiple-photocell sensor attached to the scanning system. The scanning system behaves like two rotating arrows tip to tail. The sensor is located at the outer tip. The information thus extracted is transmitted and received by means of a torque transfer synchro system and a binary-to-decimal identification code conversion. The received information is interpreted and manifested as an assembled figure, organized from cutouts of the seven specified parts of the dancer's body. The resulting figure is photographically recorded.

The operation of the self-organizing system is as follows:

1. Project information from film on scanning region.
2. Scan until an intense point of light is intercepted.
3. Orient sensor along direction of arrows.
4. Identify arrow.
5. Select correct part for organization.
6. Organize through transmission of synchro information.
7. Continue until all parts are organized.
8. Record organized figure.
9. Clear organized figure.
10. Update input information.
11. Repeat the process.

The dance routine can be modified to exhibit motions that are either pleasing or displeasing to the observer. A mathematical operator can be found that, when applied to a mathematical representation of any simple dance routine, will produce the pleasing or displeasing qualities mentioned. This device will afford an empirical check on the validity of the underlying mathematics.

Details of this work will be described in a forthcoming bachelor's thesis which will be presented to the Department of Electrical Engineering, M.I.T.

J. A. Raymond